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## Article

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# The moderating role of technological innovation on ownership structure, financing decisions and environmental accounting disclosure

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## ABSTRACT

This study investigates the effect of ownership structure (OS) and financing decisions (FD) on environmental accounting disclosure (EAD), considering the moderating role of technological innovation (TI). Despite the growing emphasis on corporate sustainability, there is limited understanding of how different ownership structures and financing choices influence EAD, particularly when moderated by TI. Drawing insights from agency and stakeholder theories, this research aims to fill this gap by analyzing manufacturing companies in the MENA region from 2001 to 2022. Using Dynamic Common Correlated Effects (DCCE) estimation, we examine the empirical relationships among these variables. To address endogeneity issues, the study employed GMM modeling. Our findings reveal that concentrated ownership and state ownership significantly promote EAD, while managerial ownership has a negative impact. Additionally, firms relying on equity financing tend to exhibit higher EAD, whereas those relying on debt financing show lower EAD levels. Notably, technological innovation positively moderates the relationship between ownership structure and EAD. The findings underscore the importance of promoting equity financing, concentrated ownership, and state ownership to enhance EAD in the MENA region. Furthermore, the study emphasizes the need for adopting innovative practices to improve environmental disclosure standards and support sustainable business practices.

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## SUBJECTS

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## 1. Introduction

Corporate sustainability has gained global prominence due to increasing awareness of environmental degradation and the need for responsible business practices (Tawiah et al., 2021; Zhou et al., 2024). Central to this effort is environmental accounting disclosure (EAD), which involves transparent reporting of a company's environmental impacts and sustainability initiatives. EAD enhances corporate transparency and fosters trust among stakeholders, reflecting a company's commitment to sustainability and its ability to manage environmental risks in evolving regulatory landscapes (Sun et al., 2023). However, significant variability in EAD reporting can lead to inconsistencies and undermine the credibility of sustainability claims, posing a challenge for stakeholders to accurately assess a company's environmental performance (Al Amosh & Khatib, 2022). The Middle East and North Africa (MENA), is known for its crucial role in global energy markets due to its abundant oil and gas reserves (Kongkuah et al., 2022; Odedyah et al., 2021). Additionally, the region faces unique challenges related to environmental sustainability and emissions intensity due to the rapid growth of its energy sector (Agyemang et al., 2023). Ownership structure in the region plays a significant role in many sectors, influencing strategic decisions and regulatory frameworks related to environmental stewardship. Given the region's economic

dependence on natural resources, sustainable practices and transparent reporting are crucial for mitigating environmental impacts and diversifying economies (Ning et al., 2024).

Ownership structure (OS) and financing decisions (FD) are pivotal in shaping corporate governance and financial strategies across MENA. OS varies widely, from ownership concentrated which includes family-owned conglomerates and institutional ownership to state-controlled enterprises. This structures of ownerships how signals companies prioritize sustainability goals and disclose environmental information (Kamil & Appiah, 2022; Kongkuah, 2023). Similarly, FD decisions, influenced by equity and debt trends, determine a company's capacity to invest in sustainability initiatives and disclose comprehensive environmental information (Alessa et al., 2024; Al-Janadi, 2021).

Technological innovation (TI), which involves creating novel solutions and enhancing methodologies to address environmental challenges and promote sustainable practices effectively (Appiah et al., 2020; Jijian et al., 2021). TI plays a crucial role in driving sustainability efforts within MENA. For instance, innovations in green technologies and R&D are particularly relevant in the region's arid climate, as they can drive sustainable development and reduce environmental impacts. TI acts as a catalyst that can amplify or mitigate the impact EAD, enabling companies to adopt advanced technologies that enhance environmental performance and compliance with international sustainability standards (Alessa et al., 2024).

Corporate sustainability is increasingly recognized as paramount on a global scale, yet there remains a notable scarcity of empirical research examining how OS and FD influence EAD, particularly in the MENA region. MENA's economic landscape is characterized by a spectrum ranging from resource-rich nations to emerging markets, amplifying the necessity to comprehend how diverse OS configurations and FD choices impact corporate sustainability practices and the transparency of environmental disclosures.

Previous studies have primarily focused on exploring relationships such as ownership structure and ESG disclosure Al Amosh and Khatib (2022) and (Black & Yahaya, 2024), ownership concentration and green accounting disclosure Chen et al. (2021) and (Fuadah et al., 2022), the impact of ownership structure on CSR reporting Al-Duais et al. (2021) and (Alshbili et al., 2020; Jamali et al., 2020), ownership structure and capital structure (Shehadeh et al., 2022), capital structure decisions and environmental performance Jamali et al. (2020) and (Touil & Mamoghli, 2020, and the influence of financing choices on environmental footprint disclosure (Buallay et al., 2020; Mertzanis et al., 2023). None of the prior studies examined integrated key dimensions of both ownership structure and financing decisions on EAD in the MENA region. Furthermore, the role of technological innovation (TI) as a moderating factor in these dynamics remains unexplored in existing literature. The closest study examined the impact of ownership structure and financing decisions on green accounting disclosure in developing countries (Chang et al., 2024). This leads to a substantial gap in the literature. Hence thi study seeks to examine the impact of OS, and FD on EAD, taken into account the moderating role of TI. Addressing these gaps is pivotal for developing effective policy frameworks and strategic initiatives that advance sustainable business practices and elevate environmental transparency across MENA economies. This study aims to explore these intricate relationships, providing empirical evidence and actionable insights to bolster corporate sustainability practices within MENA while contributing to global sustainability goals. By comprehensively investigating these dynamics, the research seeks to elucidate critical pathways for integrating OS, FD, and TI strategies that enhance EAD and promote enduring environmental stewardship across the MENA region and beyond.

The motivation behind this study stems from the urgent global need to address environmental sustainability challenges and achieve carbon neutrality targets. This research introduces novel insights in several ways: firstly, by integrating key dimensions of OS and FD to analyze their collective impact on environmental disclosure. Secondly, our study uniquely explores the potential moderating influence of TI in shaping these relationships, offering insights into how innovative sustainability practices within firms can enhance environmental disclosure. Thirdly, we innovate by proposing an index for quantifying environmental accounting disclosure through content analysis, leveraging frameworks such as SDGs, GRI standards. This methodological approach enhances the relevance and applicability of our findings. Lastly, unlike prior research, our study includes robustness and endogeneity checks, ensuring the reliability and validity of our empirical results. This comprehensive methodology is essential for guiding evidence-based policy decisions and promoting sustainable business practices in the MENA region and globally.

The research contributes significantly to the existing literature in three key ways. Firstly, it expands our understanding of how OS and FD influence EAD through the lens of stakeholder and agency theories. These frameworks allow us to analyze how different ownership types (such as concentrated ownership versus state-owned) and financing strategies (such as equity versus debt financing) impact companies' environmental disclosure practices. Secondly, by exploring the moderating role of technological innovation (TI), the study provides insights into how advancements in technology can facilitate or inhibit firms' ability to adopt and disclose sustainable practices. This aspect is crucial as it highlights the dynamic nature of corporate responses to environmental challenges in a technologically evolving world. Thirdly, the research contributes theoretically by applying stakeholder and agency theories to understand the motivations and pressures driving firms to disclose environmental information. This approach enhances our conceptual framework for analyzing the strategic decisions and external influences that shape environmental disclosure practices in organizations. Practically, the study offers implications for stakeholders such as policymakers, investors, and managers by highlighting the importance of aligning corporate governance and financial decision-making with sustainability goals. This alignment not only enhances transparency and accountability but also supports efforts towards achieving broader societal objectives of sustainable development.

The paper is organized as follows: The second section explores theoretical frameworks, empirical development, and hypotheses. The third section details the methodology employed in this study. Data analysis and results are presented in the fourth section. Finally, the paper concludes with recommendations and policy implications in the last section.

## **2. Theoretical background and hypothesis Development**

### **2.1. Theoretical background**

#### **2.1.1. Stakeholder theory (ST)**

ST asserts that organizations are accountable to a diverse array of stakeholders beyond shareholder. These stakeholders exert pressure on firms to disclose comprehensive environmental information due to their vested interests in understanding and mitigating corporate environmental impacts (Bukari et al., 2024). OS plays a pivotal role in shaping EAD practices within this framework: concentrated ownership often prioritizes sustainability to safeguard their reputation and ensure intergenerational wealth, whereas state-owned entities face governmental and societal pressures to demonstrate environmental responsibility (Ying & Jin, 2024). FD also significantly influence EAD under ST. Companies opting for equity financing are inclined to disclose robust environmental data to meet investor expectations for sustainability and transparency (Kong et al., 2023). Conversely, firms relying heavily on debt financing may focus more on short-term financial stability unless compelled by stakeholders or regulatory mandates to enhance EAD. TI acts as a critical catalyst in these dynamics by enabling advanced environmental monitoring and reporting technologies. This empowers firms to track and report environmental impacts accurately, satisfy stakeholder demands for transparency, and engage effectively with stakeholders through digital advancement strategies (Abdi & Omri, 2020).

#### **2.1.2. Agency theory (at)**

AT delves into the principal-agent relationship within organizations, emphasizing how conflicts between shareholders (principals) and managers (agents) influence managerial decisions, including those related to EAD. Managers strategically disclose environmental information to align their actions with stakeholder expectations and mitigate agency conflicts (Al-Janadi, 2021). OS significantly influences EAD practices under AT: concentrated ownership holdings like family ownership firms are driven by long-term sustainability goals to uphold their reputation and ensure continuity, whereas publicly traded firms face diverse shareholder pressures that shape their environmental disclosure strategies (Zhou et al., 2024). FD further shape EAD practices within Agency Theory. Firms funded through equity financing are motivated to disclose comprehensive environmental information to build shareholder trust and enhance transparency. In contrast, companies reliant on debt financing may prioritize short-term financial stability over comprehensive EAD practices unless compelled by stakeholders or regulatory requirements (Buallay et al., 2020).

TI plays a crucial role in influencing these dynamics by enhancing the accuracy and reliability of environmental disclosures. Technological advancements enable real-time monitoring of environmental impacts, empowering firms to proactively manage sustainability issues and respond promptly to stakeholder concerns (Buallay et al., 2020).

### 3. Empirical review and hypothesis development

#### 3.1. Ownership structure and EAD

##### 3.1.1. Managerial ownership and EAD

From the AT perspective, when managers own a significant portion of the company, they are more likely to act in the best interests of shareholders by ensuring transparent and comprehensive EAD. This reduces information asymmetry and mitigates agency conflicts, as managers are more invested in the long-term sustainability reporting and reputation of the company (Zhou et al., 2022). Meanwhile, ST suggests that companies with higher managerial ownership are more attuned to the expectations of various stakeholders, including investors, customers, and regulatory bodies, who demand greater accountability and transparency regarding environmental impacts. Consequently, managerial ownership incentivizes the adoption of robust environmental accounting practices to meet these stakeholder expectations and enhance corporate legitimacy and trust (El Khoury et al., 2023).

Prior studies that examined these nexuses revealed contradictory findings. For instance, Black and Yahaya (2024) found that higher levels of managerial ownership are associated with increased transparency and comprehensive environmental disclosure (ED) practices within firms. Managers with significant ownership stakes are more likely to ensure thorough environmental reporting to align their interests with long-term shareholder value. Similarly, Al Amosh and Khatib (2022) showed that in the MENA region, manufacturing firms with higher managerial ownership tend to have more robust environmental performance. This is because managers who are also owners are more invested in the firm's reputation and long-term sustainability, leading to more detailed and transparent environmental reporting. This was further supported by, Black and Yahaya (2024) who indicated that managerial ownership enhances influences ESG performance by enhancing corporate governance mechanisms in firms in the MENA region. Firms with substantial managerial ownership are more likely to implement rigorous environmental reporting standards, improving accountability and transparency. Contrary, Doshi et al. (2024) pointed out that high managerial ownership could potentially lead to conflicts of interest, where managers might prioritize personal or short-term financial gains over long-term sustainability goals. This can influence environmental disclosure practices negatively, as managers might underreport environmental risks or liabilities. In line with the above discussion, we hypothesize that:

*H1: In MENA Nations, higher managerial ownership is associated with increased EAD.*

##### 3.1.2. Ownership concentration and EAD

In accordance with the ST, concentrated ownership can result in less rigorous EAD, as the dominant shareholders may downplay or ignore the environmental concerns that are not aligned with their immediate financial interests, thereby undermining the broader social and environmental responsibilities of the firm (Jijian et al., 2021). Additionally, from the perspective of AT, concentrated ownership can lead to a misalignment of interests between the majority shareholders and other stakeholders, including minority shareholders and the broader community. Majority shareholders might prioritize short-term financial gains over long-term environmental sustainability, thus discouraging comprehensive EAD that could reveal negative environmental impacts or necessitate costly remedial actions (Gerged, 2021).

Several studies that examined these relationships yielded contradictory findings. For example, Fuadah et al. (2022) found that when ownership is concentrated in the hands of a few, there is less pressure to disclose comprehensive ecological information, potentially leading to selective reporting that favors the owners' interests. Similarly, Nam et al. (2024) revealed that in the MENA region, firms with concentrated ownership tend to have poorer EAD. The dominant shareholders often have the power to suppress detailed environmental reporting to avoid the costs and potential liabilities associated with



environmental compliance. Also, Kilincarslan et al. (2020) highlighted that in Malaysian firms with concentrated ownership, there might be less incentive to disclose sustainability information, as the dominant owners may prioritize short-term financial gains over long-term environmental sustainability and transparency. Conversely, Kumar et al. (2022) found that in some cases, ownership concentration can lead to better CSR disclosure, as major shareholders have the power and interest to enforce transparency and ensure that environmental risks are adequately reported to protect their significant investments. Based on majority of prior studies, we assert that:

*H2: Concentrated ownership negatively impacts EAD in MENA.*

### 3.1.3. State ownership and EAD

From the perspective of AT, state ownership can mitigate agency problems between managers and shareholders by aligning the interests of management with those of the government, which often prioritizes long-term social and environmental goals. This alignment reduces information asymmetry and encourages managers to engage in transparent EAD (Yilanci et al., 2023). Also, ST suggests that state-owned enterprises are more accountable to a broader range of stakeholders, including the public, regulatory bodies, and non-governmental organizations. This broader accountability increases the pressure on these enterprises to maintain high standards of EAD, as their operations are under greater scrutiny and they are expected to contribute to societal well-being (Moudud-Ul-Huq et al., 2023).

Majority of prior studies that examined the link between state ownership and EAD, yielded positive outcomes. For instance, Muhammad and Aryani (2021) revealed that state-owned enterprises in China tend to have better ED compared to privately owned firms. This is because the government imposes stricter regulatory requirements on SOEs to ensure they adhere to national environmental standards and policies. Similarly, Ould Daoud Ellili (2020) highlighted that state-owned firms in developing countries often have more rigorous sustainability reporting practices, as these firms are typically under greater scrutiny from both domestic and international stakeholders. The pressure to conform to global environmental standards drives better disclosure practices. Tan et al. (2022) also showed that in Indonesian state-owned enterprises, state ownership ensures adherence to government-mandated environmental reporting standards, resulting in more detailed and transparent environmental disclosure. On the other hand, Viana and Crisóstomo (2020) revealed that in the MENA region some, state ownership can negatively impact environmental disclosure practices due to potential conflicts of interest. The state may prioritize economic or political goals over environmental transparency, leading to incomplete or biased environmental reporting. Based on the above literature, we predict the following:

*H3: State ownership enhances EAD in MENA nations.*

## 3.2. Financing decisions and EAD

### 3.2.1. Equity funding and EAD

In accordance with the ST standpoint, equity funding underscores the importance of addressing the concerns of various stakeholders, including investors, customers, and regulatory bodies, who increasingly prioritize environmental sustainability and reporting practices. Enhanced EAD meets these stakeholders' expectations, fostering trust and potentially leading to a more favorable corporate reputation and increased investment (Amoah et al., 2023). Also, the AT upholds that, equity funding significantly promotes EAD by aligning the interests of managers (agents) with those of shareholders (principals). Equity investors demand transparency and accountability regarding the company's environmental impact to assess long-term risks and sustainability (Agyemang et al., 2021). Consequently, managers are incentivized to disclose comprehensive environmental information to maintain investor confidence and secure future funding.

Numerous studies that examined this association yielded positive outcomes. For example, Al-Duais et al. (2021) suggested that Pakistan firms with higher levels of equity financing tend to have more comprehensive environmental accounting disclosures. Equity investors often demand greater transparency and detailed sustainability information to assess the long-term sustainability of their investments.

Similarly, Abdi and Omri (2020) indicated that in the MENA region, companies with significant equity financing are more likely to adopt robust CSR disclosures. This is driven by the need to meet the expectations of international equity investors who demand high standards of transparency and environmental responsibility. Also, Abdi and Omri (2020) found that equity-financed firms in Jordan disclose more environmental information to reduce information asymmetry and enhance their reputation in the capital markets. Conversely, Acar et al. (2021) found that in certain European contexts, companies with high levels of equity financing might engage in selective ecological disclosure, focusing on positive aspects while downplaying or omitting negative environmental impacts. This selective reporting can mislead investors and stakeholders. In line with the above literature, we assume the following:

*H4: In MENA, EAD is significantly bolstered by equity financing.*

### 3.2.2. Debt funding and EAD

The AT asserts that, debt funding can disincentivize environmental accounting disclosure as managers may prioritize financial performance to meet debt obligations and appease creditors, often at the expense of transparency in non-financial reporting. High debt levels increase pressure to deliver immediate financial returns, leading to reduced emphasis on long-term environmental sustainability (Bukari et al., 2024). Moreover, the ST also upholds that debt holders, as primary stakeholders, typically focus on the company's solvency and financial stability rather than its environmental impact. This narrow focus undermines the interests of broader stakeholder groups, such as environmental advocates and the community, who value comprehensive environmental disclosures. Consequently, the prioritization of debt repayment and the primary concerns of creditors can limit the extent and quality of environmental accounting disclosures, failing to meet the expectations of diverse stakeholders concerned with environmental performance (Zhou et al., 2024).

Studies such as, Agyemang et al. (2023) revealed that firms with high levels of debt financing might prioritize meeting debt obligations over environmental investments, leading to lower levels of environmental performance. The pressure to maintain financial solvency can reduce the focus on sustainability reporting. This was backed by, Agyemang et al. (2021) who found that highly leveraged firms tend to have less comprehensive voluntary disclosures. The increased financial constraints associated with high debt levels can limit resources available for environmental initiatives and reporting. Al Amosh and Khatib (2022), similarly revealed that highly indebted companies are less likely to disclose detailed ESG information due to the potential negative impact on their credit ratings. Creditors may perceive extensive environmental liabilities as financial risks, leading firms to limit their disclosures. Conversely, Al-Duais et al. (2021) showed that firms with moderate levels of debt financing might improve their carbon disclosures to signal their commitment to sustainability and responsible management practices to both investors and creditors. This can enhance their reputation and reduce perceived risks. In accordance with prior studies, we predict that:

*H5: Debt financing does not foster EAD in MENA nations.*

### 3.2.3. Technological innovation, OS and EAD

The AT posits that, TI enhance monitoring and control mechanisms, allowing owners to oversee managerial decisions regarding environmental reporting more effectively. This reduces the agency costs associated with potential conflicts of interest between managers and shareholders, as transparency and accuracy in environmental reporting increase. Moreover, Stakeholder theory emphasizes the importance of TI in facilitating dialogue and engagement with various stakeholders. By leveraging innovative technologies for organizations can respond more proactively to stakeholders' environmental concerns and expectations, thereby fostering trust and long-term relationships (Alessa et al., 2024). Consequently, technological innovation not only supports governance and accountability frameworks aligned with Agency theory but also enhances stakeholder engagement, promoting sustainable environmental practices and disclosure (Ning et al., 2024).

Al-Janadi (2021) demonstrated that in the MENA region, firms with state ownership that invest in technological innovation are more likely to have robust climate-related disclosures. The state's involvement and emphasis on technological advancements facilitate better environmental reporting practices. Also, Alessa et al. (2024) found that technological innovation enhances the relationship between ownership structure and



environmental reporting positively. Firms with diverse ownership structures benefit from adopting green technologies, which enhance their ability to disclose comprehensive environmental information. On the other hand, Shehadeh et al. (2022) found that in the MENA region, technological innovation's positive impact on environmental disclosure is limited in firms with concentrated ownership. These firms might not prioritize environmental transparency despite technological advancements, focusing instead on short-term financial gains. In line with majority of prior studies, we hypothesize the following:

*H6: In MENA nations, advancements in technology positively influence both OS and EAD.*

### **3.2.4. Technological innovation, financing decisions and EAD**

Agency theory asserts that TI efforts in green technologies improve firms' ability to monitor and report environmental metrics accurately, reducing information asymmetry between managers and shareholders. This transparency incentivizes managers to choose financing options (like equity or debt) that support sustainable initiatives, aligning with shareholder interests and enhancing corporate governance (Wang et al., 2023). From the stakeholder theory viewpoint, TI demonstrate firms' commitment to environmental stewardship and responsible corporate citizenship. Innovations resulting from R&D investment streamline environmental reporting, enhancing transparency and accountability to stakeholders (Boolaky et al., 2020).

A study by Abdi and Omri (2020) revealed that companies investing in green technologies tend to provide more detailed CSR performance, which enhances their ability to secure equity financing. This is because investors are increasingly focused on environmental sustainability as a criterion for investment. This was backed by, Al Amosh and Khatib (2022) who indicated that technological innovation facilitates better environmental reporting, positively impacting financing decisions. Lenders and investors prefer to finance firms that demonstrate a commitment to environmental responsibility through the use of advanced technologies. Conversely, Acar et al. (2021) suggested that while technological innovation can enhance sustainability reporting, some firms may selectively disclose information to present a more favourable image to potential investors. This selective disclosure can mislead investors about the firm's actual environmental performance. Hence, we assume that:

*H7: Technological innovation positively influences the link between FD and EAD.*

## **4. Methodology**

### **4.1. Sampling and data sources**

In response to rising investor concerns about businesses' ability to address sustainability challenges and the urgent need to achieve carbon neutrality by 2030 Agyemang et al. (2023) and (Agyemang et al., 2021), the authors decided to focus their research on the MENA region. The authors examined various sectors and industries within this context to identify the one presenting the most significant environmental risks and threatening long-term business sustainability. Chemical manufacturing firms in the MENA region were chosen due to their significant contribution to global warming through high emissions and their crucial role in environmental sustainability issues (Zhu et al., 2024a). This sector's notable environmental impact necessitates focused research to understand and mitigate its effects effectively (Bukari et al., 2024). Using a purposive sampling method, the authors selected 142 listed chemical manufacturing firms with publicly accessible annual reports for their study. Additionally, the authors focus on environmentally sensitive chemical firms for the study. The data sources for this research were the Refinitiv database and the annual reports of the companies. The study analyzed data from 2001 to 2022, allowing us to capture long-term trends. An unbalanced panel data set consisting of 3124 observations was used due to the lack of data for certain variables and companies.

### **4.2. Diagnostic tests**

The diagnostic tests conducted in this study include a comprehensive examination of several potential issues: serial correlation, heteroscedasticity, conditional heteroscedasticity, Ramsey's RESET test for model specification, and the normality of residuals. These tests are crucial for validating the assumptions

**Table 1.** Diagnostic tests result.

Specification	Stat./p-values	Remarks
Durbin-Watson (autocorrelation)	2.234/1.799	No autocorrelation
Breusch-Godfrey (autocorrelation)	0.542/0.875	No higher-order autocorrelation
Breusch-Pagan (heteroscedasticity)	0.369/0.296	No heteroscedasticity
ARCH LM (conditional heteroscedasticity)	0.879/0.726	No conditional heteroscedasticity
Ramsey RESET (omitted variables)	0.071/0.488	No omitted variables
Jarque-Bera (normality)	0.694/0.773	Evidence of normality

underlying regression models and ensuring the accuracy and reliability of the results (Wang et al., 2023; Wen et al., 2023). Table 1 shows the diagnostic test results.

The results reported in Table 1 indicate that the model does not suffer from any issues related to misspecification, as confirmed by Ramsey's RESET test. Additionally, the tests for heteroscedasticity and conditional heteroscedasticity reveal no evidence of unequal variance among the residuals, ensuring that the assumption of homoscedasticity holds. The examination for higher-order autocorrelation shows no significant autocorrelation, suggesting that the residuals are not correlated across observations. Finally, the normality test confirms that the residuals are normally distributed. These findings collectively imply that the results from our analyses are robust and reliable, providing a solid foundation for making valid inferences and conclusions.

#### 4.3. Model

We employed a model formulated by Tawiah et al. (2021) and (Zhou et al., 2024), which provides empirical support and a strong basis for our research. To account for differences in measurement units among variables, we applied the natural logarithm to the variables. The equation for model 1 is presented as follows:

$$\ln EAD_{it} = \varphi_0 + \ln \varphi_1 MO_{it} + \ln \varphi_2 OC_{it} + \ln \varphi_3 SO_{it} + \ln \varphi_4 EF_{it} + \ln \varphi_5 DF_{it} + \gamma \sum controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \dots \dots \dots (1)$$

We replaced Equations 2 and 3 with alpha and lambda mathematical notations to differentiate the coefficients to be estimated from those of Equation 1. Hence, the moderating model is given as follows:

$$\ln EAD_{it} = \omega_0 + \omega_1 \ln MO_{it} + \omega_2 \ln(MO_{it} \times TI) + \omega_3 \ln OC_{it} + \omega_4 \ln(OC_{it} \times TI) + \omega_5 \ln SO_{it} + \omega_6 \ln(SO_{it} \times TI) + \omega_7 \ln EF_{it} + \omega_8 \ln(EF_{it} \times TI) + \omega_9 \ln DF_{it} + \omega_{10} \ln(DF_{it} \times TI) + \omega_{11} \ln TI_{it} + \gamma \sum controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \dots \dots \dots (2)$$

Furthermore, an additional robustness equation is presented as:

$$\ln ESG_{it} = \phi_0 + \ln \phi_1 MO_{it} + \ln \phi_2 OC_{it} + \ln \phi_3 SO_{it} + \ln \phi_4 EF_{it} + \ln \phi_5 DF_{it} + \gamma \sum controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \dots \dots \dots (3)$$

$\phi_0, \omega_0, \varphi_0$  denotes the intercept terms,  $\mu_i, \lambda_t, \varepsilon_{it}$  denotes industry and time effect as well as error term. The variable names can be seen in Table 3.

#### 4.3. Measurement of variables

##### 4.3.1. Environmental accounting disclosure (EAD)

This study focuses on environmental accounting disclosure (EAD) as its primary dependent variable, aiming to enhance quantitative assessment beyond previous approaches. Building on the framework introduced by Agyemang et al. (2023) and (Agyemang et al., 2021), the research refines an index tailored to include indicators aligned with Sustainable Development Goals (SDG) 12 and 13, as well as the Global Reporting Initiative (GRI) framework. Fifteen environmental dimensions are evaluated, assigning a binary score (1 for disclosed, 0 for undisclosed) based on their presence in the company's annual and sustainability reports. Scores are normalized against optimal disclosure benchmarks. This index enables a nuanced evaluation of EAD, identifying areas for enhancement and supporting sustainability performance assessments. Table 2 outlines the scoring criteria used in the evaluation.

**Table 2.** EAD checklist.

Environmental Dimensions	Code	Definition
Carbon Intensity	EAD1	Disclosure of greenhouse gas emissions per unit of production output, reflecting emissions efficiency.
Energy Efficiency	EAD2	Reporting of the ratio of output to energy input, indicating how effectively energy is used in operations.
Water Footprint	EAD3	Disclosure of Total volume of water used directly and indirectly throughout the supply chain, including water consumed and withdrawn.
Ecological Footprint	EAD4	Reporting of human demand on ecosystems, including land and resources required to support operations and activities.
Carbon Management Strategies	EAD5	Disclosure of strategies to manage and reduce carbon emissions, including carbon offset programs and carbon neutrality goals.
Environmental Performance Targets	EAD6	Setting and disclosure of specific targets for environmental performance improvement.
Air Quality	EAD7	Monitoring and reporting of emissions contributing to air pollution, including particulate matter (PM), sulfur dioxide (SO <sub>2</sub> ), and nitrogen oxides (NO <sub>x</sub> ).
Environmental Compliance	EAD8	Disclosure of Adherence to environmental laws, regulations, and standards to mitigate legal and regulatory risks.
Eco-Efficiency	EAD9	Reporting of Optimization of resource use to minimize environmental impact while maximizing economic output
Environmental Innovation	EAD10	Reporting of development and adoption of new technologies, processes, or products aimed at reducing environmental impact and improving sustainability.
Land Use	EAD11	Reporting of Management and conservation of land resources, including habitat preservation, reforestation, and land restoration efforts.
E-waste Management	EAD12	Reporting Handling and disposal of electronic waste, focusing on recycling and responsible disposal practices.
Ecosystem Restoration Projects	EAD13	Disclosure of Investments or initiatives aimed at restoring or enhancing ecosystems affected by business operations.
Stakeholder Engagement	EAD14	Disclosure of stakeholder engagement processes and outcomes related to environmental concerns.
Natural Resource Conservation	EAD15	Disclosure of efforts to conserve natural resources such as forests, biodiversity hotspots, and marine ecosystems.

**Table 3.** Summary of variables.

Category of variables	Names of variables	Acronym	Measurement	Prediction
Explained variable	Environmental accounting disclosure	EAD	environmental items disclosed in annual reports divided by the maximum disclosure score	
Explanatory Variables	Managerial ownership	MO	percentage of shares owned by top managers and directors.	+
	Ownership concentration	OC	proportion of shares held by the largest shareholder relative to the total outstanding shares.	–
	State ownership	SO	percentage of a company's shares that are owned by the state.	+
	Equity funding	EF	Ratio of equity to total assets.	+
Moderating Variable Controls	Debt Funding	DF	Proportion of total liabilities to total assets.	–
	Technological innovation	TI	Ratio of R&D expenditures to total revenue.	+
	Profitability	PRO	Ratio of net income over average total assets.	+
	leverage	LEV	The ratio of total debt to total assets	+
	Firm Size	SIZE	Natural log of total assets.	+

The EAD index is represented in equation below:

$$EAD = \frac{\sum X_{ij}}{nj} \dots \quad (4)$$

EAD: Environmental Accounting disclosure;  $n_j$ : total number of  $j$  company,  $n \leq 16$ ;  $X_{ij}$ : Total environmental items reported (1 if reported and 0 if not). Hence  $0 \leq EAD \leq 1$ .

#### 4.3.2. Ownership structure

In this study, the independent variable is ownership structure which encompasses Managerial Ownership (MO), which measures the proportion of shares held by top managers and directors within the company. Ownership Concentration (OC) assesses the percentage of shares held by the largest shareholder compared to all outstanding shares, indicating the degree of control exerted by a dominant owner. State Ownership (SO) quantifies the portion of shares owned by governmental entities or state institutions, reflecting the influence of public-sector involvement in corporate governance (Chang et al., 2024).

#### 4.3.3. Financing decision

Regarding financing decisions, Equity Funding (EF) represents the proportion of shareholders' equity relative to total assets, highlighting the reliance on internal equity for funding operations and investments.

Debt Funding (DF) measures the proportion of total debt to total assets, indicating the extent to which external borrowing finances corporate activities (Zhou et al., 2024).

#### 4.3.4. *Technological innovation*

The moderating variable, Technological Innovation (TI), is operationalized through Research and Development (R&D) expenditure as a percentage of total income. This metric captures the company's investment in innovative technologies and processes aimed at improving environmental performance and disclosure practices. Together, these variables provide a comprehensive framework for examining how ownership structures, financing decisions, and technological innovations interact to influence environmental accounting disclosure within firms (Kong et al., 2023).

#### 4.4. *Summary of study variables*

Details of the variables utilized in the study are provided in Table 3.

### 5. Empirical results and discussion

#### 5.1. *Descriptive statistics*

Descriptive statistics play a crucial role in data analysis by measuring central tendencies and variability. They provide a concise summary of the dataset, enabling researchers to understand the overall distribution, identify patterns, and detect outliers (Zhu et al., 2024b). Table 4 shows the descriptive statistics results.

The descriptive statistics reveal significant variability in several measures, with extreme values and wide dispersions around their means. EAD and OC show particularly high variability and are heavily skewed to the right, indicating the presence of outliers and a long tail of higher values. MO, on the other hand, has low variability and a slight left skew, suggesting a more consistent distribution. SO and EF also exhibit skewed distributions, with EF slightly left-skewed and SO right-skewed. DF displays moderate variability with a right skew. The leptokurtic distributions of EAD, OC, and EF imply a higher likelihood of extreme values, impacting their predictability and analysis.

#### 5.2. *Multicollinearity test*

To determine whether there is multicollinearity among the study variables, the study performed a variance inflation factor (VIF) test. Failure to account for multicollinearity leads to inflated standard errors, unreliable statistical inferences, and potentially misleading results in regression analyses (Tawiah, 2023). Table 5 shows the variance of inflation factor results.

According to the multicollinearity results presented in Table 5, the variance inflation factor (VIF) values are all below the threshold of 10, and the corresponding 1/VIF values are all greater than 0.10. This confirms the absence of multicollinearity among the study variables. As per previous literature Agyemang et al. (2023) and (Agyemang et al., 2021), a VIF greater than 10 or a 1/VIF less than 0.10 indicates potential multicollinearity issues.

#### 5.3. *Cross-sectional dependency analysis*

A significant issue in panel data analysis is cross-sectional dependence (CSD), which arises when variables across different cross-sections are correlated due to unobservable factors affecting them all. This pervasive CSD can introduce biases, potentially compromising the reliability of estimates (Boolaky et al., 2020). Ignoring CSD can lead to less reliable study results. The CSD test results are displayed in Table 6.

The Pesaran CSD test results in Table 6 indicate significant dependence within the pane. Based on the findings, the alternative assumption is substantially supported and the CSD null hypothesis is rejected. All tests reveal highly significant CSD test statistics. Consequently, estimators capable of addressing

cross-sectional dependence, such as the DCCE model, must be employed to ensure unbiased estimates and valid statistical inference.

#### 5.4. Stationarity test

The CIPS and CADF panel unit root tests are used to determine whether the variables exhibit a unit root, indicating they follow a non-stationary process (Tan et al., 2022). The results of the unit root tests are displayed in Table VII.

The results in Table 7 indicate that in levels, all variables are either stationary or trend-stationary at the 1% significance level based on the CIPS test, except SO, DF, and LEV. However, the CADF test suggests that all variables except EAD, MO, OC, and PRO have a unit root in levels. Taking first differences removes the potential unit roots - all variables are stationary according to both tests after differencing.

#### 5.5. Estimation techniques

We employed the DCCE and AMG estimators in this study to ensure robust analysis and mitigate potential issues such as endogeneity and cross-sectional dependency. The DCCE estimator was chosen for its resilience to endogeneity and ability to handle panel model complexities (Tawiah et al., 2021; Zhou et al., 2024). Additionally, we utilized the AMG estimator across all models to address endogeneity and potential heteroscedasticity effectively (Agyemang et al., 2021). Regression analyses were conducted using natural logarithms to correct curved relationships and standardize distributions, thereby enhancing statistical reliability by addressing skewness and stabilizing variance. Each model (M1 and M2) was estimated using both DCCE as the primary estimator and AMG as a robustness check. Our analysis included three panels: Panel A for Middle Eastern firms, Panel B for North African firms, and Panel C combining both regions. Table 8 presents the main estimation results.

Table 8 shows that the high adjusted R-squared values across all panels indicate that the models capture a substantial portion of the variability in how the explanatory factors impact EAD. The significant probability > f values confirm that the model fits well.

According to Table 8, the main estimation results in M1 reveal a negative and statistically significant association between managerial ownership (MO) and EAD at the 1% and 5% significance levels for panels A and C, respectively. However, panel B shows a negative but insignificant link. The robustness

**Table 4.** Descriptive analysis.

Variables	Mean	Std. Dev	Min	Max	Variance	Skewness	Kurtosis
lnEAD	13.3963	102.93	0.1320	0.9332	10237.6	8.4267	4.0821
lnMO	0.2358	.65461	0.4033	1.2010	0.56944	−0.21158	2.2125
lnOC	0.59801	7.3859	0.2032	8.2303	40.780	8.2577	7.267
lnSO	4.3390	9.5400	0.0917	3.3317	7.3932	6.7268	8.828
lnEF	2.3312	5.3393	0.4310	2.9843	18.8295	−0.35013	5.154
lnDF	12.946	7.5279	0.5498	4.9397	42.6140	1.4642	4.4497
lnTI	535.56	1477.2	1.233	9.7327	6.3413	−4.6517	2.3213
lnPRO	18.3963	182.93	0.5320	3.2748	10237.6	5.4267	7.0821
lnLEV	0.4358	.75461	−2.4033	9.2010	0.56944	−0.61465	2.9125
lnSIZE	0.59801	7.3859	312.232	819.233	40.780	8.2577	4.267

**Table 5.** Multicollinearity results.

Variables	VIF	1/VIF
lnMO	1.073	0.931
lnOC	1.414	0.707
lnSO	1.276	0.784
lnEF	1.259	0.794
lnDF	1.162	0.861
lnTI	1.132	0.883
lnPRO	1.054	0.949
lnLEV	1.051	0.953
lnSIZE	1.019	0.981
	1.159	

**Table 6.** presents the cross-sectional dependence test results.

Variable	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
lnEAD	1213.80***	102.6252***	201.6829***	45.53582***
lnMO	2534.30***	202.6232***	101.6829***	5.5176***
lnOC	13009.29	432.6484	531.8227***	161.4738***
lnSO	22460.412***	521.3573***	520.5124***	109.3123***
lnEF	4112.735***	224.159***	164.1481***	31.38253***
lnDF	2325.226	168.0342	137.0542***	15.23038***
lnTI	38921.69***	712.1065***	201.2617***	10.58160***
lnPRO	37021.91	546.359	523.7486***	266.7238***
lnLEV	643921.69***	93.1065***	261.2617***	59.58160***
lnSIZE	64281.10***	572.1735***	571.1053***	89.3523***

Note: Under the null hypothesis of cross-section independence,  $CD \sim N(0,1)$ .

\*\*\* indicates statistical significance at the 1% level.

**Table 7.** Results of unit root tests.

Variables	CIPS test-constant and trend		CADF test-constant and trend	
	Level	First difference	Level	First difference
lnEAD	-2.243*	-4.731***	-2.128*	-6.125***
lnMO	-2.463*	-5.981***	-1.528*	-8.196***
lnOC	-2.393*	-5.588***	-1.430*	-8.410***
lnSO	-2.357	-5.385***	-0.011	-8.080***
lnEF	-2.572*	-5.667***	-1.974	-2.644***
lnDF	-2.168	-3.559***	-0.299	-8.856***
lnTI	-2.372*	-5.667***	-1.974	-2.644***
lnPRO	-2.674*	-4.505***	2.243*	-2.683***
lnLEV	-2.257	-5.385***	-0.011	-8.080***
lnSIZE	-2.674*	-4.505***	2.243	-2.683***

Note: CADF and CIPS are simple panel unit root test in presence of cross section dependence.

\*\*\*, \*\*, \* represent significant levels at 1%, 5% and 10% respectively.

results in M2 are consistent with M1, suggesting that increased managerial ownership correlates with decreased EAD among chemical manufacturing firms in MENA. These findings contradict our first hypothesis and can be attributed to managerial incentives prioritizing financial goals over long-term sustainability, reducing environmental disclosure. Policymakers should consider regulations that align managerial ownership with long-term sustainability goals to enhance ecological transparency and accountability.

Ownership concentration (OC) showed a statistically significant positive relationship with EAD in M1 at the 1% and 10% significance levels for panels B and C, respectively, while panel A showed a positive but statistically insignificant link. The robustness analysis in M2 supports these findings, indicating that concentrated ownership is positively linked with higher levels of environmental disclosure in MENA. This result contradicts our second hypothesis and can be attributed to increased oversight and alignment of interests between large shareholders and sustainable practices, fostering responsible environmental stewardship. Policymakers should incentivize ownership structures that encourage concentration to positively influence ecological disclosure through increased monitoring and alignment of interests between large shareholders and sustainability objectives.

The primary estimation findings in M1 reveal a strong positive and statistically significant association between state ownership and environmental disclosure, with significance levels of 1% and 5% for panels B and C, and a positive but insignificant link in panel A. The robustness analysis in M2 confirms this relationship, reinforcing the reliability of the findings and validating our third hypothesis. State ownership appears to drive higher levels of environmental disclosure in MENA chemical manufacturing firms, likely due to the influence of strict regulatory frameworks and oversight mechanisms that prioritize environmental transparency and accountability. Governments should thus use state ownership to elevate environmental disclosure standards, fostering policies that promote transparency and sustainability reporting in state-owned enterprises.

Regarding equity financing, the primary estimation findings show a statistically significant positive relationship with EAD at the 5% and 1% levels for panels A and B, respectively, and a positive but insignificant link in panel C. The robustness results in M2 align with the main findings in M1, suggesting that



**Table 8.** Baseline regression.

Variables	Pannel A		Pannel B		Pannel C	
	M1	M2	M1	M2	M1	M2
InMO	−0.0411*** (0.0121)	−0.0371** (0.0141)	−0.0821 (0.0424)	−0.0629 (0.0237)	−0.1141** (0.0381)	−0.0512*** (0.1413)
InOC	0.0534 (0.0826)	0.0401 (0.0621)	0.0761*** (0.0801)	0.0435** (0.0089)	0.03141* (0.0127)	0.0843*** (0.041)
InSO	0.0321 (0.0133)	0.070 (0.022)	0.0651*** (0.0218)	0.0655** (0.0289)	0.0811** (0.0294)	0.0531*** (0.0217)
InEF	0.0671** (0.0301)	0.0307*** (0.0917)	0.0488* (0.0322)	0.0811**** (0.0294)	0.0901 (0.0479)**	0.0713 (0.0036)
InDF	−0.0621*** (0.0261)	0.0522* (0.0258)	−0.0657 (0.0479)	−0.3151 (0.0427)	0.1761** (0.0801)	−0.0524 (0.0312)
InPRO	0.0836* (0.0369)	0.0497* (0.0181)	0.0477** (0.0236)	−0.0321** (0.0125)	0.0321 (0.0287)	0.1207*** (0.029)
InLEV	0.0903*** (0.0313)	0.1323** (0.058)	0.0645** (0.0351)	−0.0291 (0.0144)	0.0134 (0.0015)	0.3281*** (0.041)
InSIZE	0.0721* (0.0479)	−0.0357 (0.0259)	0.1052*** (0.0427)	0.0688* (0.0322)	0.0811*** (0.0194)	−0.063** (0.021)
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes	Yes
Sargan Test/ Wald chi (2)	289.27	3409.22	169.5	2545.31	397.64	5886.34
Adj. R (2) /Prob> chi(2)	0.561	.0000	0.673	.0000	0.712	.0000
Obs	2178	2179	946	946	3124	3124

Note: Standard errors are enclosed in parentheses.

\*\*\*, \*\*, \* represent significant levels at 1%, 5% and 10% respectively.

firms relying on equity financing demonstrate higher levels of environmental disclosure among MENA chemical manufacturing firms. These results support our fourth hypothesis, indicating that equity investors' alignment with sustainability goals and preference for transparent environmental reporting incentivize firms to disclose more comprehensive environmental information. Policymakers and financial regulators should promote equity financing to enhance environmental disclosure practices, acknowledging the positive link between equity financing and transparency in environmental reporting, which could attract socially responsible investors and improve market perceptions.

Regarding debt financing (DF), the primary estimation findings in M1 reveal a statistically significant positive relationship with EAD at the 1% and 5% levels for panels A and C, respectively, and a negative but insignificant link in panel B. The robustness results in M2 confirm these findings, providing strong empirical support. These results suggest that firms relying on DF tend to exhibit lower levels of environmental disclosure, consistent with our fifth hypothesis. This can be attributed to the risk aversion associated with DF, leading firms to prioritize financial stability over environmental transparency. Policymakers should consider measures to mitigate the negative impact of DF on environmental disclosure, such as promoting environmentally responsible lending practices and encouraging transparency in reporting environmental risks to debt holders. DF may constrain firms' ecological disclosure practices due to the need to meet short-term financial obligations.

## 5.6. Moderating analysis

Table 9 displays the moderating analysis.

The moderating results in Table 9 show a statistically positive association between managerial ownership (MO) and EAD across all panels in the primary estimation (M1). The interaction effect demonstrates a positive and significant relationship with EAD at the 5%, 1%, and 10% levels, indicating that firms with high managerial ownership and strong innovation report more environmental information. The robust findings support these results. Similarly, concentrated ownership positively correlates with EAD, and the interaction effect of technological innovation (TI) is significant at the 1% and 5% levels, highlighting that innovation enhances the impact of concentrated ownership on EAD. State ownership also shows a positive and significant link with EAD, with innovative state-owned firms reporting more environmental information.

The interaction effect of the moderating variable (TI) resulted in an increased coefficient, supporting our sixth hypothesis. This suggests that firms with higher innovation capacity are better equipped to navigate ownership structure complexities and enhance environmental transparency and sustainability.

Innovative firms are more proactive in reporting environmental information, viewing it as a strategic advantage. Policymakers should foster innovation within firms to improve EAD and implement incentives or regulations to promote transparency and accountability.

Regarding financing decisions, the interaction effects significantly enhance the relationship between equity financing (EF) and EAD at the 1%, 5%, and 1% levels across all panels. This suggests that innovative firms relying on EF disclose more environmental information. Both main estimation findings and robustness results are consistent. Additionally, the interaction effect of technological innovation (TI) shows a significant positive relationship between debt financing (DF) and EAD at the 5%, 10%, and 1% levels, indicating that innovative firms relying on DF also increase their environmental disclosures. Robustness findings align with the main estimation results.

This positive moderation implies that technologically innovative firms strategically use financial resources for sustainable initiatives and transparently report their environmental performance. Innovation amplifies the positive impact of financing decisions on environmental disclosure by facilitating efficient resource allocation and signaling a commitment to sustainability. Policymakers should enhance TI to maximize the benefits of financing decisions on environmental disclosure and create regulations that promote sustainable financing practices.

### 5.7. Additional robustness results

We conducted additional tests to validate our findings against external factors. By substituting EAD with ESG performance, we aimed to verify if the effects of financing decisions (FD) and ownership structure (OS) on ESG performance align with the results in Table 8. For this robustness check, as shown in Table 10, we used the pooled mean group estimator, which effectively addresses endogeneity and

**Table 9.** Moderating outcomes.

Variables	Pannel A		Pannel B		Pannel C	
	M1	M2	M1	M2	M1	M2
MO	0.6864*** (0.0556)	0.5434** (0.0627)	0.3845** (0.0349)	0.5285 (0.0362)	0.3602*** (0.0447)	0.3252*** (0.144)
MO × TI	0.0895** (0.0248)	0.2170* (0.0265)	0.0932*** (0.0268)	−0.1265 (0.0732)	−0.1242* (0.0048)	−0.9318*** (0.0241)
OC	0.3045** (0.2061)	0.4231** (0.0128)	0.2143** (.0134)	0.4210 (0.0208)	0.2341** (0.0416)	0.1341* (0.0237)
OC × TI	0.1231*** (0.0258)	0.0794* (0.0159)	0.0981*** (0.0242)	0.0849 (0.0659)	0.7846** (0.0217)	0.0863** (0.0324)
SO	0.3456*** (0.0260)	0.4195* (0.0125)	0.3485*** (0.4256)	−0.5241 (0.0339)	0.4274*** (0.0166)	0.2168** (0.0219)
SO × TI	0.0851*** (0.0143)	0.4364* (0.0142)	0.08106** (0.0508)	−0.0913 (0.0265)	0.0654* (0.0188)	0.0835** (0.0025)
EF	0.4631** (0.3795)	0.1006** (0.1053)	0.3738 (0.0379)	0.4074 (0.0166)	0.3245** (0.0161)	0.4358** (0.0213)
EF × TI	0.0645*** (0.00081)	0.0823 (0.0026)	0.1034** (0.002)	0.0782* (0.0006)	0.0635* (0.0025)	0.1024*** (0.00081)
DF	−0.1219** (0.0549)	−0.3198** (0.015)	−0.2043 (0.0031)	−0.107*** (0.0029)	−0.4118** (0.293)	−0.1019** (0.0549)
DF × TI	0.0793** (0.0026)	0.0834* (0.002)	0.0831* (0.0016)	−0.07543*** (0.0211)	0.1039*** (0.069)	0.7649*** (0.0218)
TI	0.0958*** (0.0315)	0.1079** (0.0031)	0.0679** (0.0219)	0.1597 (0.0132)	0.0827* (0.0233)	0.0737*** (0.0122)
PRO	0.0289 (0.0026)	0.0365* (0.0013)	0.0724*** (0.0014)	0.0542 (0.0232)	−0.0766*** (0.0518)	−0.0631*** (0.0428)
LEV	0.0413*** (0.0151)	−0.0254* (0.0039)	−0.0128 (0.00428)	0.0896*** (0.02939)	0.07122*** (0.0293)	0.0973*** (0.0194)
SIZE	0.0613*** (0.0251)	0.0544*** (0.0539)	0.0128 (0.00428)	−0.0896* (0.0329)	0.0196*** (0.0052)	0.0627** (0.0348)
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes	Yes
Sargan Test/ Wald chi-squared	3174.27	4334.22	1253.5	6449.31	473.24	6905.46
Adj. R (2) Test/ Prob > chi(2)	0.571	.0000	0.535	.0000	0.682	.0000
Obs	2178	2179	946	946	3124	3124

Note: Standard errors are enclosed in parentheses.

\*\*\*, \*\*, \* represent significant levels at 1%, 5% and 10%, respectively.

heteroscedasticity issues (Agyemang et al., 2023). To analyze the impact of various OSs and FDs on EAD across different sectors in the MENA region, we categorized firms into three sectors: pharmaceuticals (Panel A), agrochemicals (Panel B), and petrochemicals (Panel C), with Panel D including all sampled chemical manufacturing firms. The robustness results are presented in Table 10.

The robustness results reveal a substantial negative link between managerial ownership and ESG performance across all panels. These findings suggest that firms with high managerial ownership tend to exhibit low levels of ESG performance. Also, concentrated ownership positively correlates with ESG performance across all panels. This indicates that ownership concentration in firms is tied to high levels of ESG performance, underscoring the influence of concentrated OSs on fostering transparency and accountability in environmental practices. Moreover, State ownership exhibits a positive and significant relationship with ESG performance in panels A and D, with a positive but insignificant link in panels B and C. This suggests that state-owned firms have high levels of ESG performance, reflecting the potential influence of government policies and regulations on promoting sustainability practices in state-owned enterprises. Furthermore, equity financing demonstrates a significant positive link with ESG performance across panels A, B, and C, with an insignificant link in panel D. This implies that firms relying on equity financing tend to have high ESG performance, highlighting the role of equity investors in promoting sustainability practices and transparency. Conversely, DF reveals a statistically significant link with ESG performance in panels A, C, and D, with an insignificant link in panel B. This indicates that firms dependent on DF have lower ESG performance, suggesting potential challenges associated with DF in fostering sustainability practices. In essence, the robustness findings correspond with the main estimation findings in Table 8, validating the reliability and accuracy of our results and providing robust policy implications for promoting sustainable business practices.

### 5.8. Endogeneity checks

This study conducts crucial endogeneity checks in regression analysis using instrumental variables such as GMM and 2SLS estimators to address biases from independent variables and error term which can be as a result of reverse causality or omitted variables. Failure to account for endogeneity issues leads to biased, inconsistent, and potentially misleading estimates of the relationship between variables, which can result in incorrect conclusions and policy recommendations (Buallay et al., 2020; Chang et al., 2024). GMM offers flexibility across various endogeneity types and conditions, ensuring robustness against misspecification (Al-Duais et al., 2021). The study utilized the 2SLS estimator due to its ability to address issues of endogeneity, reverse causality, omitted variable bias, simultaneity bias, and selection bias, providing a consistent and unbiased estimate of the causal relationship between the variables (Arayssi et al., 2020). By applying both instrumental variables the study's results are valid and reliable. Table 11 shows the results of these endogeneity tests, offering robust insights into the examined relationships.

The endogeneity results reported in Table 11 align with the main estimation findings presented in Table 8, indicating the absence of biases such as reverse causality, omitted variables, and measurement errors. This alignment underscores the reliability and validity of our findings, crucial for informing effective policy decisions.

### 5.9. Discussion of results

In line with agency theory, higher managerial ownership aligns managers' interests closely with shareholders, reducing agency costs and promoting transparent reporting of environmental performance to safeguard firm value. This alignment ensures managers prioritize long-term sustainability and manage environmental risks, enhancing accountability and investor confidence. From a stakeholder theory perspective, significant managerial ownership signifies a commitment to stakeholders beyond shareholders, including employees, customers, and the community. By disclosing comprehensive environmental information, managers meet stakeholder expectations for ethical conduct and sustainable practices, fostering trust and enhancing the firm's reputation. Hence, our study hypothesized a positive link between managerial ownership and EAD, but our results indicate the opposite, leading to the rejection of our first hypothesis. Our findings align with those of Agyemang et al. (2021) and (Al Amosh & Khatib, 2022), who

**Table 10.** Robustness test.

Variables	Pannel A	Pannel B	Pannel C	Pannel D
lnMO	−0.0534*** (0.0231)	−0.0392** (0.0238)	−0.0491 (0.0163)	−0.0604** (0.0221)
lnOC	0.0628*** (0.0598)	0.1036** (0.0794)	0.0629 (0.0312)	0.0521*** (0.0218)
lnSO	0.0715*** (0.0241)	0.0921 (0.0431)	0.0162 (0.0091)	0.5125*** (0.0811)
lnEF	0.0815*** (0.0137)	0.1265** (0.0225)	0.0743*** (0.0264)	0.0423 (0.0127)
lnDF	−0.0613*** (0.0231)	−0.0716 (0.0258)	−0.0439** (0.0321)	−0.0623*** (0.0206)
lnPRO	0.0736* (0.0388)	−0.0723** (0.0337)	0.0161*** (0.002)	0.3727*** (0.0967)
lnLEV	0.4287*** (0.0521)	−0.0218* (0.0152)	−0.0259*** (0.0013)	0.0423** (0.0127)
lnSIZE	0.5417*** (0.0852)	−0.3212** (0.0671)	0.5694*** (0.113)	−0.5219** (0.0331)
Year effect	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes
Wald chi-squared statistic	845.51	575.51	423.41	1634.27
Prob > chi-squared	0.002	0.000	0.046	0.000
Adj. R squared	0.521	0.624	0.665	0.784
Obs	1782	726	616	3124

Note: Standard errors are enclosed in parentheses.

\*\*\*, \*\*, \* represent significant levels at 1%, 5% and 10%, respectively.

also found a negative effect of managerial ownership on environmental performance. This contrasts with Acar et al. (2021), who reported a positive impact of managerial ownership on ESG disclosure.

In accordance with the agency theory, high ownership concentration among a few large shareholders or insiders may reduce pressure on managers to transparently disclose detailed environmental information. This lack of oversight can prioritize short-term financial gains over long-term sustainability concerns. From a stakeholder theory perspective, concentrated ownership limits diverse perspectives in decision-making, potentially neglecting environmental issues important to broader stakeholder groups like employees, communities, and environmental organizations. Consequently, ownership concentration may reduce the quality and transparency of environmental accounting disclosure, impacting stakeholder trust and the company's reputation for environmental responsibility. Based on this foundation our study assumed a negative link between ownership concentration and EAD, our results unexpectedly showed a positive outcome, leading to the rejection of our second hypothesis. Our findings align with (Al Amosh & Khatib, 2022), who found that ownership concentration promotes carbon emissions disclosure. However, our results differ from Black and Yahaya (2024), who reported an adverse impact of ownership concentration on environmental footprint disclosure.

Drawing from a stakeholder viewpoint, state ownership cultivates trust and confidence among citizens, environmental groups, and investors by demonstrating a commitment to environmental responsibility and public interest. Also, from an agency theory perspective, State-owned enterprises (SOEs) operate under stringent oversight and accountability mandated by government regulators, ensuring transparent reporting of environmental risks and impacts. This regulatory alignment reduces agency costs by mitigating potential conflicts of interest between managers and shareholders, focusing managerial efforts on long-term sustainability and compliance with environmental regulations. Based on this premise, we hypothesized a positive association between state ownership and EAD. Our results support this hypothesis, as we observed a positive outcome. Hence, we accept our hypothesis. This finding is consistent with Tawiah et al. (2021) and (Zhou et al., 2024), who also found a positive link between state ownership and sustainability reporting. However, our results differ from Chang et al. (2024) and (Ning et al., 2024), who reported a positive link between state ownership and CSR reporting.

Consistent with the agency theory, equity financing, where companies raise funds by issuing shares to investors, enhances transparency and accountability. Companies relying on equity financing are motivated to attract investors who prioritize transparency and sustainability practices. Therefore, there is a strong incentive for firms to disclose comprehensive environmental accounting information, demonstrating their commitment to managing environmental risks and promoting sustainability reporting. From the stakeholder perspective, equity financing builds trust and credibility among investors, customers, and

**Table 11.** Endogeneity results.

Variables	Panel A		Panel B		Panel C	
	GMM	2SLS	GMM	2SLS	GMM	2SLS
L.InEAD	0.5134 (0.0321)		0.4814 (0.0521)		0.3621 (0.0245)	
InMO	−0.0322*** (0.0127)	−0.0406** (0.00211)	0.05231*** (0.0721)	−0.0671** (0.0431)	−0.0492** (0.0238)	−0.0761** (0.0912)
InOC	0.0308** (0.0152)	0.05121*** (0.0018)	0.04728*** (0.0218)	0.0661 (0.0216)	0.04136** (0.0094)	0.0815*** (0.0127)
InSO	0.546*** (0.0142)	0.5125*** (0.0811)	0.7157*** (0.0719)	0.4187 (0.0511)	0.0921* (0.0431)	0.2103*** (0.0412)
InEF	0.0482** (.0136)	0.1252** (0.0751)	0.1387** (0.0921)	0.2161** (0.0679)	0.0285* (0.0125)	−0.6173*** (0.0414)
InDF	0.0646 (0.0425)	0.0423** (0.0127)	−0.0815*** (0.0137)	0.3132** (0.0617)	0.1265** (0.0225)	−0.2135*** (0.0214)
InPRO	0.0675 (0.0421)	0.0763*** (0.0206)	0.2013*** (0.0234)	0.0412** (0.0177)	0.0716 (0.0558)	0.0218* (0.0215)
InLEV	0.424*** (0.047)	0.3727*** (0.0967)	0.0736* (0.0388)	0.2014** (0.0636)	−0.0723** (0.0337)	−0.3212** (0.067)
InSIZE	0.5219** (0.0331)	0.5417*** (0.0852)	−0.305** (0.066)	0.3212** (0.0671)	0.8124* (0.0312)	−0.0863*** (0.0206)
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry effect	Yes	Yes	Yes	Yes	Yes	Yes
AR (2)	0.413		0.421		0.425	
Hansen Test	0.527		0.682		0.13	
R-squared		0.512		0.521	5	0.672
F-Statistics		37.26**		46.36**		29.73***
Obs	2030	2178	730	946	2760	3124

Note: Standard errors are enclosed in parentheses.

\*\*\*, \*\*, \* represent significant levels at 1%, 5% and 10%, respectively.

communities who increasingly value corporate social responsibility and environmental disclosure practices. In line with this rationale, we hypothesized a positive association between equity financing and Environmental Accounting Disclosure (EAD). Our results support this hypothesis; hence we accept our fourth hypothesis. Our findings correspond with those of Chang et al. (2024) and (Mertzanis et al., 2023), who also found that equity funding significantly promotes ESG reporting. However, our results contradict those of Al-Duais et al. (2021), who reported an adverse impact of equity financing on environmental performance.

In accordance with the stakeholder perspective, heavy reliance on debt financing may shift corporate priorities towards short-term financial goals, compromising resources allocated to environmental management and transparency efforts. Stakeholders, who increasingly prioritize environmental responsibility, expect comprehensive disclosure of environmental impacts and risks (Agyemang et al., 2023). Moreover, from the agency theory viewpoint, companies heavily reliant on debt may prioritize short-term financial performance to meet debt obligations, potentially reducing investment in environmental management and disclosure. Based on this theoretical framework, we hypothesized a negative relationship between debt financing and EAD. Surprisingly, our fifth hypothesis was not supported, as our results indicate a positive association. This finding contrasts with Agyemang et al. (2021) and (Alessa et al., 2024), who found that debt financing exerts an adverse impact on sustainability reporting. However, our results differ from Bukari et al. (2024) and (Kong et al., 2023), who reported a favorable link between debt financing and CSR disclosure.

From an agency theory standpoint, increased technological advancement allows firms to develop advanced environmental monitoring technologies and data analytics tools. This capability enhances the accuracy and timeliness of environmental performance measurement and reporting, aligning managerial incentives with shareholder interests in transparency and sustainable practices. Additionally, stakeholders benefit as R&D investments in environmental technologies enhance the quality and scope of EAD. Investors and the public increasingly value companies that demonstrate commitment to sustainability through innovative solutions and robust environmental reporting. Based on these premises, we hypothesized that technological innovation significantly enhances the link between ownership structure and EAD. Our assumptions align with our results, thus supporting our sixth hypothesis. Our findings are consistent with Fuadah et al. (2022) and (Nam et al., 2024), who found a positive impact of technological advancement on the relationship between ownership structure and ESG performance. However, our

results differ from Wen et al. (2023), who reported a favorable impact of technological innovation on the relationship between ownership concentration and CSR disclosure.

The stakeholder posits that, technological advancements improve the accessibility and clarity of EAD meeting the growing demand for environmental transparency from investors, customers, and regulatory bodies. Enhanced EAD through technological innovation strengthens the perception of corporate responsibility and sustainability practices, thereby bolstering stakeholder confidence and supporting long-term value creation. Additionally, from an agency theory standpoint, companies opting for equity financing are incentivized to utilize technological innovations to enhance transparency and accountability to shareholders. This alignment fosters trust and enhances governance, ensuring that managerial actions prioritize long-term sustainability reporting. Based on this justification, we hypothesized a positive association, and our results support this assumption, leading us to accept our seventh hypothesis. Our findings align with those of Bukari et al. (2024) and (Kong et al., 2023), who found a positive relationship between technology adoption and ecological footprint disclosure in equity financing. However, our results differ from Wang et al. (2023), who reported an unfavorable impact of technological advancement on the relationship between equity financing and ESG performance.

## 6. Conclusion and policy implications

### 6.1. Conclusion

This study investigated the impact of Ownership Structure OS and FD on EAD in the MENA region, with a focus on the moderating role of Technological Innovation (TI). The research utilized a quantitative sourcing data from chemical manufacturing companies spanning from 2001 to 2022, employing Dynamic Common Correlated Effects (DCCE) and Augmented Mean Group (AMG) estimators. The findings indicate that concentrated ownership and state ownership in manufacturing firms within the MENA region positively influence Environmental Accounting Disclosure (EAD). Conversely, managerial ownership shows a negative impact on EAD. Furthermore, companies that rely on equity financing tend to exhibit higher levels of EAD compared to those relying on debt financing. The study also reveals that TI moderates these relationships positively, suggesting that advancements in technology can enhance firms' environmental performance and transparency in disclosure practices.

### 6.2. Theoretical implications

Integrating Stakeholder Theory and Agency Theory in this study has yielded a robust framework for understanding the influence of OS and FD on EAD. This integration has enriched theoretical understanding by illustrating how diverse stakeholder pressures and managerial incentives shape corporate sustainability practices. The study emphasizes the dynamic interplay of these factors, underscoring the importance of contextual elements such as TI in shaping EAD outcomes. Moving forward, theories must increasingly incorporate these contextual factors to comprehensively address sustainability challenges in organizational contexts.

### 6.3. Practical implications

On a practical level, the study offers actionable strategies for firms seeking to enhance environmental transparency and sustainability practices. It highlights the potential of concentrated ownership to align sustainability goals with managerial decisions, thereby improving the quality of EAD. Moreover, promoting equity financing over debt financing can foster transparency and stakeholder trust, prompting proactive environmental disclosures. Furthermore, the study underscores the pivotal role of technological innovation in the facilitating real-time monitoring of environmental impacts and enhancing the accuracy of EAD reporting. Continued investments in TI are crucial for enhancing corporate environmental performance and meeting evolving stakeholder expectations effectively.



#### 6.4. Policy implications

From a policy perspective, the findings provide insights for policymakers aiming to incentivize sustainable practices within corporate governance frameworks. Recommendations include promoting equity financing and supporting technological advancements in environmental monitoring to create an environment conducive to robust EAD practices. Tailoring policies to different OS configurations can further enhance environmental governance and accountability across diverse ownership structures. Ultimately, these implications contribute to advancing theoretical insights and practical strategies, thereby promoting sustainable business practices and enhancing environmental transparency in organizational settings worldwide.

#### 6.5. Limitations and future directions

Limitations of this study include its focus on manufacturing firms within the MENA region from 2001 to 2022, potentially limiting generalizability across other sectors and regions. Reliance on secondary data sources may introduce biases and restrict data availability and quality. While the study acknowledges the moderating role of Technological Innovation (TI), the specific mechanisms of TI's impact on OS, FD, and EAD were not fully explored. Additionally, the cross-sectional design prevents establishing causal relationships among variables, suggesting the need for longitudinal or experimental approaches for deeper insights. Future research should consider investigating mediating factors like organizational culture and leadership styles, along with conducting comparative studies across different global regions and industries to broaden understanding and enhance applicability of findings.

#### Authors' contributions

Conceptualization [UFS, IW and RK], Data curation [IW], Methodology [UFS and RK], Formal analysis and discussion [UFS], writing of original draft [IW and RK], Reviewing and Editing [IW].

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## Data availability statement

The study utilized secondary data obtained from the Refinitiv database, as well as companies' annual reports and financial statements. Access to the data and materials supporting this research will be available upon request.

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